APPENDIX C: TOTAL EXPOSURE RATIO

The Total Exposure Ratio (TER) is calculated by combining all SAR measurements and power density measurements after normalizing to their respective limits. The general expression is below.

$$TER = \sum_{a=1}^{A} \frac{SAR_a}{SAR_a, limit} + \sum_{b=1}^{B} \frac{psPD_b}{psPD_b, limit} < 1$$

The TER shall be less than unity to ensure compliance with the limits.

$$\sum_{n=1}^{N} \frac{4G\ SAR_n}{4G\ SAR_n, limit} + \sum_{m=1}^{M} \frac{5G\ mmW\ NR\ psPD_m}{5G\ mmW\ NR\ psPD_m, limit} + \sum_{p=1}^{P} \frac{WLAN\ SAR_p}{WLAN\ SAR_p, limit} < 1$$

Qualcomm® Smart Transmit algorithm for WWAN adds directly the time-averaged RF exposure from 4G and time-averaged RFexposure from 5G mmW NR. Smart Transmit algorithm controls the total RF exposure from both 4G and 5G mmW NR to not exceed FCC limit. Therefore, per FCC guidance, TER does not need to be evaluated directly for the 4G and 5G simultaneous compliance via summation. The following equations are derived later in Appendix C. The validation of the time-averaging algorithm and compliance under the Tx varying transmission scenario for WWAN technologies are reported in Part 2 report. The report SN could be found in Bibliography section.

$$\sum_{n=1}^{N} \frac{4G\ SAR_n}{4G\ SAR_n, limit} + \sum_{p=1}^{P} \frac{WLAN\ SAR_p}{WLAN\ SAR_p, limit} < 1$$

$$\sum_{m=1}^{M} \frac{5G\ mmW\ NR\ psPD_m}{5G\ mmW\ NR\ psPD_m, limit} + \sum_{p=1}^{P} \frac{WLAN\ SAR_p}{WLAN\ SAR_p, limit} < 1$$

For 5G mmW NR, since there is total design-related uncertainty arising from TxAGC and device-to-device variation, the worst-case RF exposure should be determined by accounting for device uncertainty. Therefore, 5G mmW NR RF exposure for this DUT is evaluated by reported psPD calculated as:

$$reported\_psPD = PD\_design\_target + PD\_uncertainty$$

Note that since not all the beams supported by this EUT are measured, *reported_psPD* cannot be computed based on limited *measured psPD* data. Alternatively, since *measured psPD* for all the beams will be ≤ *PD_design_target* + *PD_uncertainty* uncertainty, *reported_psPD* is computed based on this worst-case psPD as shown above.

The compliance analysis for simultaneous transmission scenarios of WWAN (4G LTE & 5G mmW NR) with Smart Transmit and 4G & WLAN can be found in two reports indicated in the table below.

This appendix demonstrates compliance for the 5G + WLAN/BT scenarios. The report SNs can be found in Bibliography section.

	Simultaneous Scenario	**Evaluation Report**
1.	4G LTE WWAN + WLAN	FCC SAR Evaluation Report (Part 1)
2.	4G LTE WWAN + 5G mmW NR WWAN	RF Exposure Part 2 Test Report

RF exposure compliance with 5G mmW NR WWAN+WLAN simultaneous transmission scenarios is demonstrated for various radio configurations below.

Note that the above *reported psPD* applies to the worst-case surfaces of the DUT at 2mm evaluation distance.

Worst-case PD on other surfaces of the DUT are calculated from simulated PD data (see Power Density Simulation Report), by multiplying reported psPD with the highest proportion out of all beams and out of all three channels in each band, where the adjustment for each beam/channel is computed as the proportion of “simulated PD on desired surface” to “simulated PD on worst-surface”. For example, to determine worst-case PD on front surface, highest proportion of (simulated PD on front surface)/(simulated PD on worst surface) was determined out of all supported beams and out of all three channels by the DUT in each band.

In some cases, the simulation vs measurement for some surfaces can exceed the device's total uncertainty. In those cases, if the measured psPD > simulated adjusted psPD (assuming a linear congruency of the psPD across surfaces), then measured psPD should be used towards the simultaneous TX analysis. Table C-1 lists the relevant worst-case reported psPD values based on the additional surfaces and evaluation distances needed to perform the TER analysis. The highest of the adjusted Reported_psPD and Measured Total psPD was chosen for TER analysis and the chosen values are indicated by bolded psPD values.

Table C-1
5G mmW NR FR2 psPD

NR Band	Antenna	Surface	Evaluation Distance (mm)	Adjustment Factor due to Simulation	Adjusted Reported psPD (W/m^2)	Measured Total psPD (W/m^2)	Final Reported psPD (W/m^2)
n258	M0	Back	2	0.035	0.252	2.960	**2.960**
n258	M0	Front	2	1.000	7.130	4.320	**7.130**
n258	M0	Top	2	0.057	0.408	-	**0.408**
n258	M0	Bottom	2	0.014	0.099	-	**0.099**
n258	M0	Right	2	0.437	3.119	3.900	**3.900**
n258	M0	Left	2	0.017	0.119	-	**0.119**
n258	M2	Back	2	0.590	4.210	1.380	**4.210**
n258	M2	Front	2	0.622	4.436	1.250	**4.436**
n258	M2	Top	2	1.000	7.130	5.310	**7.130**
n258	M2	Bottom	2	0.001	0.011	-	**0.011**
n258	M2	Right	2	0.014	0.097	-	**0.097**
n258	M2	Left	2	0.205	1.462	1.880	**1.880**
n258	M3	Back	2	0.559	3.986	1.430	**3.986**
n258	M3	Front	2	0.587	4.188	2.680	**4.188**
n258	M3	Top	2	0.001	0.009	-	**0.009**
n258	M3	Bottom	2	1.000	7.130	3.120	**7.130**
n258	M3	Right	2	0.219	1.561	0.397	**1.561**
n258	M3	Left	2	0.012	0.087	-	**0.087**
n261	M0	Back	2	0.039	0.279	0.107	**0.279**
n261	M0	Front	2	1.000	7.130	3.160	**7.130**
n261	M0	Top	2	0.032	0.230	-	**0.230**
n261	M0	Bottom	2	0.018	0.127	-	**0.127**
n261	M0	Right	2	0.440	3.139	1.020	**3.139**
n261	M0	Left	2	0.010	0.070	-	**0.070**
n261	M2	Back	2	0.606	4.323	2.240	**4.323**
n261	M2	Front	2	0.618	4.409	2.190	**4.409**
n261	M2	Top	2	1.000	7.130	3.490	**7.130**
n261	M2	Bottom	2	0.001	0.005	-	**0.005**
n261	M2	Right	2	0.019	0.135	-	**0.135**
n261	M2	Left	2	0.216	1.542	0.067	**1.542**
n261	M3	Back	2	0.566	4.036	1.350	**4.036**
n261	M3	Front	2	0.590	4.207	0.098	**4.207**
n261	M3	Top	2	0.001	0.005	-	**0.005**
n261	M3	Bottom	2	1.000	7.130	4.490	**7.130**
n261	M3	Right	2	0.206	1.471	0.472	**1.471**
n261	M3	Left	2	0.017	0.121	-	**0.121**
n260	M0	Back	2	0.059	0.422	0.214	**0.422**
n260	M0	Front	2	1.000	7.130	4.170	**7.130**
n260	M0	Top	2	0.058	0.415	-	**0.415**
n260	M0	Bottom	2	0.015	0.105	-	**0.105**
n260	M0	Right	2	0.697	4.968	2.000	**4.968**
n260	M0	Left	2	0.076	0.540	-	**0.540**
n260	M2	Back	2	0.758	5.407	2.450	**5.407**
n260	M2	Front	2	0.599	4.268	0.053	**4.268**
n260	M2	Top	2	1.000	7.130	4.710	**7.130**
n260	M2	Bottom	2	0.006	0.041	-	**0.041**
n260	M2	Right	2	0.014	0.103	-	**0.103**
n260	M2	Left	2	0.183	1.302	0.278	**1.302**
n260	M3	Back	2	0.783	5.585	2.640	**5.585**
n260	M3	Front	2	0.530	3.776	1.880	**3.776**
n260	M3	Top	2	0.004	0.031	-	**0.031**
n260	M3	Bottom	2	1.000	7.130	3.500	**7.130**
n260	M3	Right	2	0.189	1.347	0.403	**1.347**
n260	M3	Left	2	0.017	0.123	-	**0.123**

Note: Adjusted factor is (simulated PD on desired exposure plane)/(PD on worst-surface at 2mm evaluation distance) out of all beams and out of all channels. See Power Density Simulation Report.

Table C-2
5G mmW NR NR Body Total Exposure Ratio with psPD from mmWave Ant M0

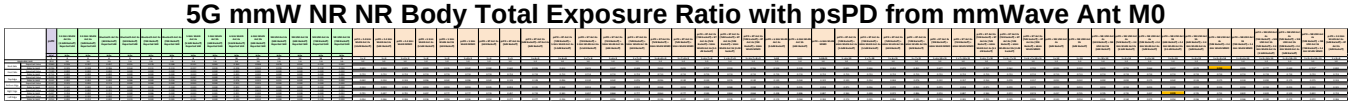


Table C-3
5G mmW NR NR Body Total Exposure Ratio with psPD from mmWave Ant M2

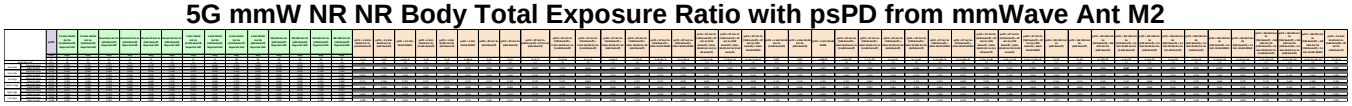
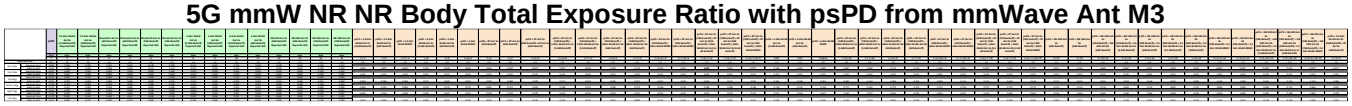


Table C-4
5G mmW NR NR Body Total Exposure Ratio with psPD from mmWave Ant M3



*TER for back side between certain antenna pairs was excluded due to the spatial separation of the antennas per 248227 Section 6.1 and as described in 80-w2112-4 section G.1.3.

TER for back side between Ant M0 and Ant 2a, Ant M2 and Ant 2a, Ant M3 and Ant 4a were excluded due to the spatial separation of the antennas per KDB 248227 Section 6.1 and as described in 80-w2112-4 section G.1.3. In the below plots, it is demonstrated that the -10 dB contours of the SAR distributions have no overlap with the area for power density. The spatial separation analysis between the SAR distributions of Ant 2a and Ant 4a
can be found in the Part 1 SAR report.

Back Side Spatial Separation Plots

Figure C-1
Back Side Spatial Separation for Antenna M2 and Antenna 2a

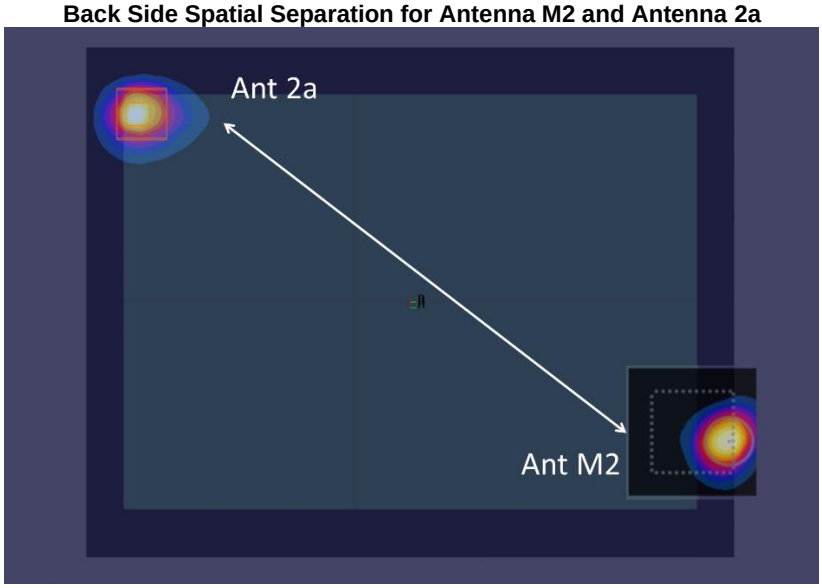


Figure C-2
Back Side Spatial Separation for Antenna M3 and Antenna 4a

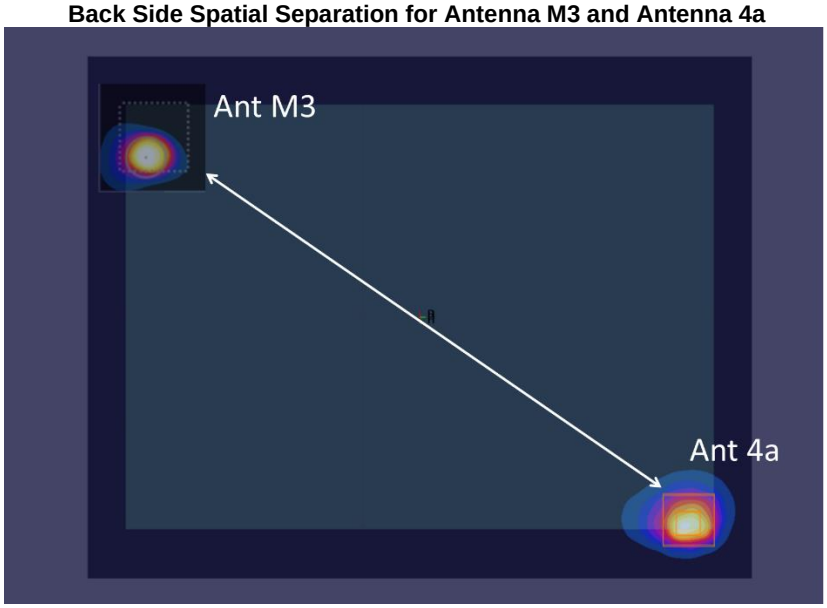
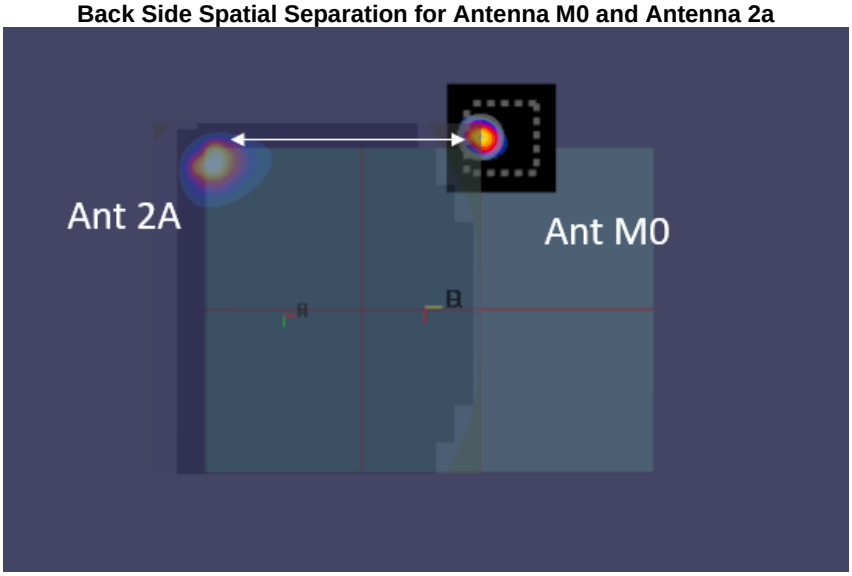


Figure C-3
Back Side Spatial Separation for Antenna M0 and Antenna 2a



Notes:

1. Worst-case power density results for each test configuration among all supported bands were considered for TER analysis.
2. Per KDB Publication 248227 D01v02r02, SAR for MIMO was evaluated by following the simultaneous SAR provisions from KDB Publication 447498 D01v06 by evaluating the sum of the 1g SAR values of each antenna transmitting independently.
3. Per FCC guidance, for power density measurements, a test separation distance of 2 mm was used for tablet configuration due to probe restraints.
4. The worst-case between Adjusted Reported_psPD and Measured Total psPD was chosen for TER analysis. The bolded psPD values in Table C-1 indicate the worst-case Reported psPD used in TER analysis.
5. Per FCC guidance, the positions that are not required to be evaluated for tablet SAR are not considered for TER analysis.

The above numerical summed PD and SAR for all the worst-case simultaneous transmission conditions were below the Total Exposure Ratio. Therefore, the above analysis is sufficient to determine no further test cases are required and that simultaneous transmission is compliant to the FCC RF Exposure Limit.

Mathematical Derivation of TER Compliance

$$Total\ Normalized\ RFx\ =\ Normalized\ RFx_{\ Time\ Averaged\ WWAN} + Normalized\ RFx_{\ WLAN}\ \leq\ 1.0 \quad (1)$$

Since WWAN Smart Transmit algorithm adds directly the time-averaged RF exposure from 4G and time-averaged RF exposure from 5G mmW NR, per chipset manufacturer's guidance, Normalized RF exposure from 4G and from 5G mmW NR could be assumed as

$$Normalized\ RFx_{\ Time\ Averaged\ WWAN} = \frac{4G\ SAR}{4G\ SAR\ Limit} + \frac{5G\ mmW\ NR\ psPD}{5G\ mmW\ NR\ psPD\ Limit} \leq\ 1.0 \quad (2)$$

Smart Transmit algorithm assumes that 4G and 5G mmW NR hotspots are co-located and therefore:

$$Time\ Averaged\ WWAN = [\ x(t)\times A] + [(1\text{-}x(t))\times B] \leq 1.0\ Normalized\ Limit \quad (3)$$

A = Max normalized time-averaged SAR exposure from 4G
B = Max normalized time-averaged PD exposure from 5G mmW NR

x(t) = Ranges between [0,1]
x(t)× A = Percentage of normalized time-averaged RF exposure from 4G
(1-x(t))× B = Remaining percentage of RF exposure contribution from 5G mmW NR

Smart Transmit controls "*x*" in real time such that the sum of these exposures never exceeds 1.0 Normalized Limit. If the equations below (4a, 4b) are proven, then, mathematically equation (5) would be proven.

$$A\ +\ norm.\ SAR\ from\ WLAN \leq 1.0\ normalized\ limit \quad (4a)$$

$$B\ +\ norm.\ SAR\ from\ WLAN \leq 1.0\ normalized\ limit \quad (4b)$$

$$[x(t)\times A] + [(1-x(t))\times B] +\ norm.\ SAR\ from\ WLAN \leq 1.0\ normalized\ limit \quad (5)$$

Without 5G mmW NR, Smart Transmit limits the maximum RF exposure contributed from 4G to 100% normalized exposure. Therefore,

$$Smart\ Tx\ WWAN:\ A = max\ (normalized\ SAR\ exposure\ from\ 4G) \leq 1.0\ normalized\ limit \quad (6a)$$

$$Smart\ Tx\ WWAN:\ B = max\ (normalized\ PD\ exposure\ from\ 5G\ mmW\ NR) \leq 1.0\ normalized\ limit \quad (6b)$$

To demonstrate simultaneous transmission compliance in equation (1), below equations (7a & 7b) obtained by combining equations (4a & 4b) and (6a & 6b), should be proven for simultaneous transmission compliance:

$$Total\ Normalized\ RFx\ =\ Normalized\ SAR_{\ 4G\ WWAN} + Normalized\ SAR_{\ WLAN} < 1.0 \quad (7a)$$

$$Total\ Normalized\ RFx\ =\ \ Normalized\ psPD_{\ 5G\ mmW\ NR\ WWAN} +\ Normalized\ SAR_{\ WLAN} < 1.0 \quad (7b)$$

which are re-written as:

$$Total\ Normalized\ RFx\ =\ \frac{4G\ SAR}{4G\ SAR\ Limit} + \frac{WLAN\ SAR}{WLAN\ SAR\ Limit} < 1 \quad (8a)$$

$$Total\ Normalized\ RFx\ =\ \frac{5G\ mmW\ NR\ psPD}{5G\ mmW\ NR\ psPD\ Limit} + \frac{WLAN\ SAR}{WLAN\ SAR\ Limit} < 1 \quad (8b)$$

Analysis for equation (8a) is performed in Section 11 of FCC SAR Evaluation Report (Part 1). Analysis for equation (8b) is performed in this appendix, Tables C-2, C-3. and C-4.